Y/SW-0077

Overview of DYMCAS, the Y-12 Material Control and Accountability System

Presented at the 42nd INMM (Institute of Nuclear Materials Management)
Annual Meeting, Indian Wells, California

David Alspaugh
Software Engineering

July, 2001

Prepared by the
Y-12 National Security Complex
Oak Ridge Post Office Box 2009
Oak Ridge, TN 37831-8169

Managed by
BWXT Y-12, L.L.C.
for the
U.S. DEPARTMENT OF ENERGY
under contract No. DE-AC05-00OR22800

Overview of DYMCAS, the Y-12 Material Control and Accountability System

ABSTRACT

This paper gives an overview of DYMCAS, the material control and accountability information system for the Y-12 National Security Complex. A common misconception, even within the DOE community, understates the nature and complexity of material control and accountability (MC&A) systems, likening them to parcel delivery systems tracking packages at various locations or banking systems that account for money, down to the penny. A major point set forth in this paper is that MC&A systems such as DYMCAS can be and often are very complex. Given accountability reporting requirements and the critical and sensitive nature of the task, no MC&A system can be simple. The complexity of site-level accountability systems, however, varies dramatically depending on the amounts, kinds, and forms of nuclear materials and the kinds of processing performed at the site. Some accountability systems are tailored to unique and highly complex site-level materials and material processing and, consequently, are highly complex systems. Sites with less complexity require less complex accountability systems, and where processes and practices are the same or similar, sites on the mid-to-low end of the complexity scale can effectively utilize a standard accountability system.

In addition to being complex, a unique feature of DYMCAS is its integration with the site production control and manufacturing system. This paper will review the advantages of such integration, as well as related challenges, and make the point that the effectiveness of complex MC&A systems can be significantly enhanced through appropriate systems integration.

BACKGROUND

The Y-12 National Security Complex, previously known as the Oak Ridge Y-12 Plant, is operated by BWXT Y-12, L.L.C. for the Department of Energy in support of national nuclear defense policies. BWXT Y-12, a company formed from resources out of BWX Technologies, Inc. and Bechtel National, Inc., assumed operations for Y-12 on November 1, 2000. The Y-12 Complex is located in Oak Ridge, Tennessee.

Y-12 is one of the premier manufacturing facilities of the DOE Nuclear Weapons Complex. It covers 811 acres of the Bear Creek Valley approximately 2.5 miles long and a half mile wide. It has over 700 buildings containing 7.6 million square feet of laboratory, research and development, machining, dismantlement, and storage areas. Y-12 is an integral part of the weapons complex with missions in the re-manufacture, surveillance, assessment, storage, processing, and disposition of uranium, lithium and secondary components of the nuclear stockpile. Y-12 is the nation’s “Fort Knox” of highly enriched uranium, the leader in uranium and lithium materials research, development and processing, and the country’s assembly and disassembly plant for nuclear weapon secondary components. Every weapon in the stockpile has some components manufactured at the Y-12 Complex.

With these missions comes responsibilities for safeguarding nuclear material in accordance with national and international nonproliferation policies and agreements. One important safeguard is a material control and accountability program supported by an effective MC&A information system.

DYMCAS OVERVIEW

DYMCAS, the Dynamic Special Nuclear Material Control and Accountability System, is the material control and accountability information system for theY-12 Complex and, as such, is a Y-12 mission-critical system.Y-12 relies on DYMCAS to assist in preventing or detecting loss of nuclear material through theft, diversion, or error, to assure rapid reconciliation of nuclear material inventories, and to facilitate timely notification and reporting of nuclear material shipments and receipts to and from the site. DYMCAS performs MC&A functions in support of DOE Order 474, *Control and Accountability of Nuclear Materials*, and other related orders and regulations. It was developed and is being maintained by the Y-12 Software Engineering Department. The Y-12 Nuclear Material Control and Accountability (NMC&A) Department is the system's administrative owner. DYMCAS functionality is tailored to the unique material processing requirements of the Y-12 Complex in accordance with detailed business rules specified by NMC&A.

DYMCAS tracks data about nuclear material - about the location, amount, identity, and form of nuclear material. Changes in attribute values that occur as material is moved or used in manufacturing operations are captured in near-real-time in DYMCAS transactions. DYMCAS provides information on the current value of an attribute (e.g., the current location of an item) as well as historical values (e.g., previous locations for an item at any given time). It tracks material in piece parts, sub-assemblies and assemblies as well as material in mop water, hand wipes, and filters. DYMCAS tracks information about every item in Y-12 that contains nuclear material. It tracks the weight of the nuclear material item, and, in addition, tracks the weight of specific nuclear elements contained in the item (e.g., uranium), and the weight of specific nuclear isotopes in the element (e.g. U-235). DYMCAS can track multiple isotopes within each element and multiple elements within each item. DYMCAS stores data in a 10 GB database that contains 760 distinct data attributes and 2,500 total attribute occurrences in 230 database tables. The database contains approximately 200,000 items. The system handles around 200,000 accountability transactions monthly.

Nuclear material inventories are managed within a site by material balance area (MBA). Approximately 40 MBAs are defined for Y-12. Physical inventories of nuclear materials are conducted at regular intervals, some frequently and others less frequently depending on the MBA and type of material. Inventory data uploaded into DYMCAS marks the end of an MBA inventory period and the beginning of the inventory reconciliation process in which NMC&A, using DYMCAS inventory data and transaction history information, performs a discrete item reconciliation and weight reconciliation. A discrete item reconciliation accounts for each item, comparing items inventoried with "book" items in DYMCAS. The weight reconciliation accounts for each gram of nuclear material. Weights are reconciled at the item, element, and isotope level for each material type in each MBA. For example, the amount of U-235 isotope for a specific uranium material concentration type is reconciled within an MBA, much as you would reconcile a checkbook, using the formula BI + TI – TO = EI (beginning inventory weight + weight of material transferred in – weight of material transferred out = ending inventory weight). Inventory differences occur when the left side of the equation doesn't equal the right side (or BI + TI – TO – EI = ID). A custodian in each MBA is assigned responsibility along with NMC&A for the inventory period reconciliation process, i.e., for assuring that items containing nuclear material are accounted for and that the amount of nuclear material items, elements, and isotopes are accounted for.

DYMCAS is required to track nuclear material and accurately record credits and debits of grams of material at the item, element and isotope level. This is complicated in an environment where item-material information breaks down, as it does in fabrication, recovery, and other Y-12 operations (more on this later).

DYMCAS provides 12 data collection transactions: Transfer, Transfer Void, Receipt Verification Step 1, Receipt Verification Step 2, Disposition/Creation, Convert Item Identifier, Build/Add-to Assembly, Disassemble/Delete/Replace Assembly, Apply/Remove TID, Weigh, Assign Lot Attribute, and Makeup/Breakup Sealed Collection. It provides Emergency Inventory capability, supports Propagation of Variance ID limit calculations, handles error processing, and provides inventory and shipment information to the DOE-wide Nuclear Material Management and Safeguards System (NMMSS) and shipment information to the Weapons Information System (WIS). Over 120 menu forms provide NMC&A and other users with access to information and software for monitoring, managing and controlling material processing.

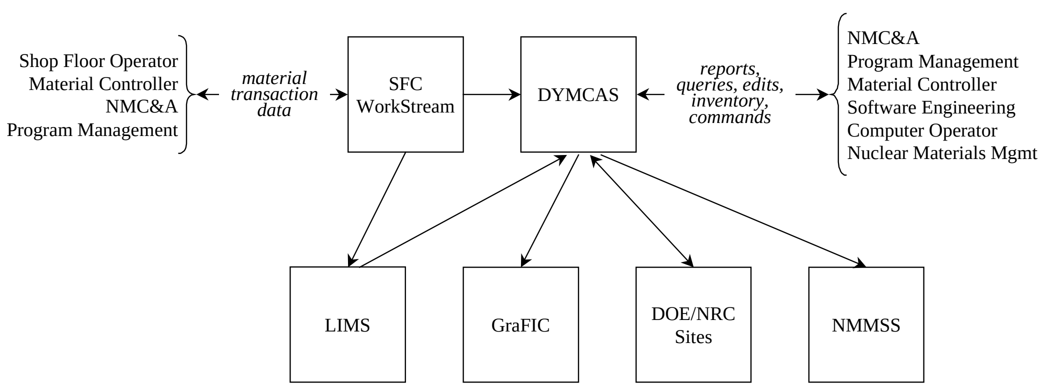

Figure 1, System Overview

The DYMCAS application has 480 software modules, provides 70 programmed reports online or printed, and provides NMC&A with ad hoc query capability using Microsoft Access. The DYMCAS database uses Oracle database server software and most of the application was developed using Oracle PL/SQL, Oracle Forms, and Oracle Reports. Accountability data is classified up to Secret RD. Extensive effort went into designing

DYMCAS to be the most secure and reliable system in Y-12 with need-to-know access control enforced down to the database row level, layers of redundancy in the hardware, data, networks and power supply, and effective continuity of operations features and plans. Interfaces were built between DYMCAS and the Y-12 Shop Floor Control System, the Laboratory Information System, the Graphical Facility Information Center, and the national NMMSS and WIS systems.

DYMCAS is a high maintenance system requiring continuous modifications to keep pace with changing business practices, information needs, regulations, computer technology, etc. Since the completion of the DYMCAS development project in June, 2000, one software version release a week containing 8.4 software changes, on average, has been implemented. The volume of change will stabilize some as the system matures, but the dynamic nature of the software will continue throughout its life cycle, reflecting the dynamic nature of the business.

Software Engineering is in the last months of an eight-year DYMCAS development project which is replacing a legacy Y-12 DYMCAS, in operation since 1982, with a totally new DYMCAS. This development project integrates DYMCAS with the Y-12 Shop Floor Control (SFC) System such that accountability data transactions are collected in the field through the SFC user interface and sent to DYMCAS.

DYMCAS-SFC INTEGRATION

Y-12's first DYMCAS system was a stand-alone system on dedicated hardware, designed as such in part to maximize MC&A security and partly because many systems at that time were developed as stand-alone systems. Consequently, shop floor operators were required to enter similar weapons material transaction data into two or three or sometimes four separate systems. Generally, the same transaction data was entered into different systems by different people at different times of the day.

A key objective of Y-12 managers in developing its new DYMCAS system was to implement a single point of entry for weapons material data. In 1992, Y-12 installed a new Shop Floor Control (SFC) system using WorkStream, a COTS package from Concilium, Inc. Y-12 designated WorkStream to be the single user interface for collecting material transaction data and directed that DYMCAS utilize WorkStream, with its data collection capabilities and presence on the shop floor, as, in effect, a data collection engine. SFC is a manufacturing execution system used to develop manufacturing plans which define specific operations and routes for material products, to schedule and track parts through manufacturing steps, and to capture data as parts are processed through fabrication, assembly, disassembly, inspection, etc. There is significant overlap in the items and data maintained in the DYMCAS and SFC systems.

Figure 1 shows this integration. Material transactions containing accountability and/or manufacturing data are entered by shop floor operators into WorkStream, verified and automatically routed to DYMCAS. WorkStream and DYMCAS maintain separate databases - the WorkStream database designed for current and planned manufacturing activities and the DYMCAS database for current and historical accountability activities.

The advantages of this kind of integration in a manufacturing environment are: reduced operating costs, enhanced data integrity, enhanced nuclear material control, and consistently applied business rules. Operating costs are reduced in several ways. A single point of data entry, where data is manually entered one time into one system, (1) eliminates the manual effort and related cost of entering data redundantly into separate systems, (2) reduces the cost of correcting data entry errors which occur far more frequently in multiple systems, where the same data is entered by different people at different times, and (3) reduces the effort necessary to reconcile data entered separately and possibly inconsistently into different systems, where such inconsistency would call into question the integrity of the data in both systems. The cost savings for this kind of effort is estimated at over $3 million a year. Also, significant computer hardware and related administrative costs are reduced for integrated systems.

Confidence in the accuracy and currency of data, the life-blood of an MC&A system, is greatly enhanced in DYMCAS because DYMCAS is integrated with the manufacturing execution system. With DYMCAS a part of the manufacturing process, accountability data has fewer data entry errors and is collected and recorded in the database as the material processing activity occurs, thus the timeliness and quality of accountability data are significantly enhanced. Our experience with a stand-alone MC&A system is that data entered offline away from the operation some time after the fact by people not involved with the operation contains more entry errors and is unnecessarily delayed. In a facility with a focus on manufacturing, accountability is improved when it's part of the manufacturing process.

Nuclear material control is improved because accountability business rules are embedded in automated SFC manufacturing plans. The processing and handling of nuclear material must follow pre-defined manufacturing routes and operations, thereby providing a rigor for moving and using nuclear material that's not available in stand-alone systems. Systems integration also forces integration of material-related business rules, presenting the shop floor operator with a consistent way of handling material. Throughout the development of DYMCAS and continuing on in system maintenance, frequent meetings with personnel from NMC&A, Program Management (the SFC system owner), and Software Engineering are conducted to discuss and implement consistent material handling rules that can be supportive of both business areas.

The integration of DYMCAS and Shop Floor Control has provided the most effective and cost-efficient way of conducting MC&A in the Y-12 manufacturing environment. There are, however, costs associated with integrating systems. Integration can be a slow, complicated, and expensive process. It can add to the complexity of systems development and maintenance, albeit generally in a positive and explicit manner where issues are identified and addressed. Often, the cost and complexity in maintaining stand-alone systems is hidden.

DYMCAS took longer and required more effort to develop and deploy due to its integration objective. The broader scope of the analysis and design imposed by integration slowed the development process. The integration team was larger and members had to understand a broader set of requirements and settle on consensus ways of conducting business. Effective communications, a key to success for integration projects, takes time and commitment.

System maintenance is also taxed by integration. An unscheduled downtime for one system may impact the other; scheduled downtimes must be closely coordinated. Synchronization of vendor software releases can be an issue. Error corrections made to data in one system must be automatically or administratively coordinated with the other to maintain proper synchronization. Similarly, software changes made to one system may impact the other and should be duly administered. Again, communications is a key to success.

Overall, the gains afforded by integrating DYMCAS with manufacturing execution software in terms of enhanced cost efficiencies, data quality, material control capability, and more consistent business practices far outweigh the costs and delays associated with integration.

NATURE OF MC&A AT Y-12

The metrics cited above - volume of data, numbers of transactions, etc. - are external indicators of technical challenges addressed by DYMCAS. A major factor in the degree of complexity of a system, however, is internal to the application, contained in a myriad of programming specifications reflecting business rules for processing data. DYMCAS has just 12 data collection transactions, but hundreds of business rules are programmed into these to properly record each transaction in light of a complicity of factors such as material type and form, area, operation, etc. The following high-level processing and material flow overview of some of the operations at Y-12 provides insight into the task confronting DYMCAS. Nowhere in the Weapons Complex does accountability for nuclear material present a greater challenge than at the Y-12 Complex. The amount of in-process material is significantly greater, the complexity of the material flows is significantly higher, and the number of material forms is significantly larger than at other locations. In Y-12, over 100 material forms (metal, salt, gas, mixed oxides, coolant, mop water, etc.) are defined for nearly 30 types of nuclear material (lithium, thorium, various concentrations of uranium, etc.).

The site accountability system tracks and reconciles grams of nuclear material down to the isotope level. Where the net, element, and isotope weights for an item are measured and remain constant, such as for items in assemblies or in long-term storage, MC&A tracking and reconciliation is straightforward. Where weights and concentrations change and are unmeasured for a period of time, and, while they are unmeasured, are moved to different MBAs, accountability becomes exponentially more complex.

In most of the Y-12 areas, nuclear material in items is measured and remains constant. Three MBAs in particular, however, handle in-process material in fabrication and material recovery operations where a significant amount of material is unmeasured and where unmeasured material-flows cross MBA boundaries. In the Casting, Machining-

Rolling-Forming, and Recovery MBAs, tracking material and crediting and debiting MBAs accurately for material receipts and transfers is a tedious and complex task.

Figure 2 gives a high-level view of material flows in the Y-12 fabrication and recovery operations, where various types of metal containing nuclear material are combined, cast, rolled, formed, and machined to make a product. In the Casting operation, metals are placed in a furnace, heated to a molten state to fit a mold, cooled, knocked out of the mold, and the resulting billets are transferred to the Machining, Rolling, and Forming MBA. Appropriate DYMCAS transactions record the various casting operations and ledger transfer entries.

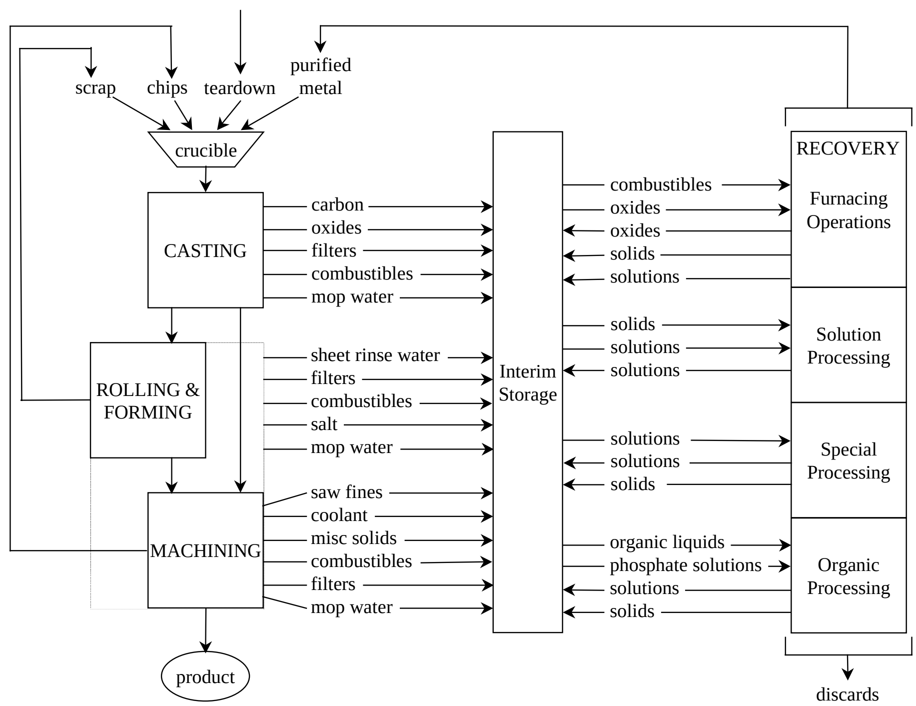

Figure 2, Metal Fabrication & Recovery

Billets go through one or more operations in Machining, Rolling and Forming depending on the fabrication objective. Billets are rolled into sheet metal, parts are stamped out of sheet metal, and unfinished parts are machined to exact shapes and sizes within stringent tolerances and the resulting product is cleaned and moved to the next manufacturing step.

In fabricating a product, these areas generate a significant amount of metal scrap and unmeasured waste by-products. Metal scrap from rolling and forming operations and chips from machining operations are collected, weighed, and transferred directly back to Casting. Waste byproducts, which are created as material is heated up, cooled down, rolled out, cut, sawed, shaped and finished, must be recovered and measured in order to support both accountability and manufacturing - accountability so that the MBAs involved can receive accurate credit for the material, and manufacturing so that this valuable material can be put back into the fabrication stream.

Recovery operations are performed in a separate MBA. Unmeasured waste by-products are collected in fabrication MBAs and transferred to the Recovery MBA - sometimes through an interim storage MBA - so that nuclear material can be extracted and measured. In Casting, furnace operations create carbon and oxide residues. Periodically, the furnaces are cleaned out and these residues are collected for Recovery. When casting molds are cleaned, residues are collected or some may be scattered and are collected later in sweepings or mop water. Some of the material is retained in hand wipes which are also collected for transfer to Recovery (shown as combustibles in Figure 2). Airborne material is captured in furnace or HVAC system filters and collected periodically for Recovery. Cutting operations in Machining creates saw fines which are collected. Some turnings from lathes collect in hand wipes and mop water that are sent to Recovery.

In the Recovery MBA, waste by-products go through a series of physical and chemical processing steps, some of which create additional waste by-products which must be recovered. Depending on the material type and form, waste materials are processed through furnaces, tanks, various kinds of equipment and hundreds of feet of pipe to get the material to a measurable state where element and isotope concentrations can be determined through laboratory sample analyses. In Recovery, material residue in furnaces, pipes and equipment are cleaned out periodically and measured or scientifically estimated to account for material in equipment. Every effort is made to recover as much material as possible, measure it, and credit the appropriate MBA with the appropriate amount of material and in so doing support the weight reconciliation process and provide Y-12 and DOE managers with a high degree of assurance that nuclear material is accurately tracked and accounted for. In a manufacturing environment such as Y-12, every gram of uranium will not be appropriately accounted for and some material will be consumed in the process. Some IDs will be generated but should be within acceptable limits.

In these processes, unmeasured material goes through a series of being combined with and extracted from other materials, thereby creating a complex trail of material flows in DYMCAS. At a point, material extracted in the recovery processing stream is in a measurable state and sample results from laboratory analyses have established element and isotope concentration values. DYMCAS must be smart enough to recognize this point for scores of products and apply accurate credits and debits of material to the appropriate MBAs.

SUMMARY

The material control and accountability system used in the Y-12 dismantlement, manufacturing, and storage facility must be highly secure, reliable, and functional. DYMCAS functionality must support complex Y-12 material forms and flows and, as a result, is a highly complex system, targeted specifically for Y-12 operations. In this complex manufacturing environment, integrating MC&A and manufacturing execution systems maximizes functional effectiveness and cost efficiency for the site.